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SPREAD FACTORS OF PESTICIDAL SPRAY FORMULATIONS ON KROMEKOTE CARDS

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ABSTRACT

To determine spherical drop size from a known spot size on a particular sampling surface it is necessary to know the spread factor for drops of pesticidal formulations. A vibrating reed apparatus is an excellent droplet generator for oil-base formulations. Magnesium oxide coated slides were used as a reference surface to determine spread factors for Kromekote cards. Uniform size droplets were collected by the two sampling surfaces and spread factor estimates were made from their ratios. Spots are made visible by use of dyes such as Brilliant Sulpho Flavine FFA, Rhodamine B, Nigrosine, and Sudan Deep Black. Spread factors for approximately 60 formulations are summarized. Several problems related to spread factor determination are discussed.

Keywords: Pesticide application methods, spraying (aerial), pesticide preparations.

INTRODUCTION

To understand the effects of aerial application of pesticides, it is important to determine relationships between target effect and spray factors such as drop density, atomization, and gallons per acre. Spray deposit assessment is the key to the determination of these factors.

As the latter two factors require actual drop diameters, we must employ a corrective spread factor to the stain marks on our sampling surface to find the actual drop size. This conversion or spread factor is the ratio of the diameter of the stain to the diameter of the drop causing it.

The determination of a particular spread factor involves the production, collection, and measurement of groups of uniform size droplets from which a calibration curve can be made.

This paper summarizes the spread factor determination on white paper Kromekote cards for various pesticidal formulations.

MATERIALS AND METHODS

Uniform spherical droplets were produced by means of a vibrating reed apparatus (fig. 1) similar to that described by Davis (1951) and Maksymiuk and Moore (1962). The reed, which bore a needle affixed at the end, was vibrated at resonance to produce maximum amplitude. As the needle passed through the liquid emanating from a hypodermic syringe, streams of droplets were formed (fig. 2).

Figure 1.--Droplets produced by vibrating reed droplet generator are caught on sampling tray.

Figure 2.--Two streams of uniform size droplets are produced by the vibrating reed.

A water manometer was used to provide a constant flow of liquid from the syringe. Back lighting provided easy viewing of the stream of droplets. Uniform size droplets, 50 to 500 micrometers (μm) in diameter, were produced by varying the amplitude of the reed vibration, needle size, flow rate, and reed position in the liquid emanating from the syringe.

Dyes were added to the spray formulation to make the spots visible. Mainly fluorescent dyes were used, such as Brilliant Sulpho Flavine FFA (BSF) and Rhodamine B extra S which are water soluble, and Rhodamine B extra base, an oil-soluble dye. Nonfluorescent dyes, Nigrosine, a black water-soluble dye, and Sudan Deep Black, an oil-soluble dye, were also used occasionally. The dye concentration was 0.1 gm per 100 ml (0.1 percent W/V) in all the spray formulations except as noted in the tables. All of the dyes mentioned here are manufactured by General Dyestuff Division, General Aniline and Film Corp. (GAF), 435 Hudson Street, New York 14, N. Y.[1/]

Spread factor was determined by passing cards and magnesium oxide (MgO) coated slides through a stream of uniform droplets produced by the vibrating reed apparatus and then performing the necessary measurements and calculations. The spherical drop diameter is the diameter of the crater formed by the droplet penetrating the MgO coating multiplied by a conversion factor of 0.86. According to May (1950) this conversion factor varies slightly with droplet size. The thickness of the MgO coating must be at least the diameter of the impinging drops. The slides and cards are viewed with a binocular microscope with a reticle containing a calibrated scale inserted in one of the oculars. With transmitted light, the inside diameters of the craters are readily visible and easily measured (in our case to the nearest 50 μm). Depending on the dye used, the spots on cards are viewed with reflected white or ultraviolet light and their outside diameters measured to the nearest 50 μm. Before measuring, sufficient time must be allowed for the spots to cease spreading. The time needed will depend on the type of formulation. Water-base formulations reach their maximum spread in less than 1 hour, whereas oil-base formulations will continue to spread for several hours.

Variation is minimized by using the mean of 10 spots or drops from each card and its corresponding slide. These values are used in the following formula for the spread factor determination of that drop size:

$$\text{spread factor} = \frac{\text{outside spot diameter on card}}{\text{inside MgO crater diameter} \times 0.86} .$$

To account for the variation of spread factor with drop size, the spread factor must be determined for the working range of drop sizes. Maksymiuk and Moore (1962) found that the relationship between the drop diameter and spot diameter for fuel oil number 2 was linear for drops larger than 125 μm. A linear regression equation can, therefore, be conveniently used to convert spot diameters to drop diameters.

[1/] The mention of products and companies by name does not constitute endorsement by the USDA, nor does it imply approval of a product to the exclusion of others which may also be suitable.

RESULTS AND DISCUSSION

The first table is concerned with microbial insecticidal formulations for *Bacillus thuringiensis* (Dipel and Thuricide) and the Douglas-fir tussock moth nucleopolyhedrosis virus (NPV). These are all water-base formulations and have spread factors in the vicinity of 2.00. Two formulations were filtered, and one was decanted because the complete formulation would not flow through the syringe needle. The data obtained for these three should not be construed as representing the complete formulation.

Table 1--*Spread factor and linear relationship between spot (y) and drop (x) diameter for microbial insecticides on Kromekote cards*

Formulation	Dye[1/]	Mean spread factor	Range (spherical drop diameter μm)	Linear regression equation	Correlation coefficient
1/2 lb Dipel WP in 25% CIB (cargill insecticide base-molasses) and H_2O to make 1 gal (filtered)	Rhod B S	1.82	80-400	Y=2.02X-34.37	0.9970
1 lb Dipel WP in 25% CIB, and H_2O to make 1 gal (filtered)	Rhod B S	1.81	112-425	Y=2.22X-87.00	.9900
1/2 lb Dipel WP in 25% CIB, 3.2% Maywood formula, and H_2O to make 1 gal	BSF	2.42	86-387	Y=2.02X+77.26	.9832
1/2 lb Dipel WP in 25% CIB, 3.2% Maywood formula, 3% Chevron sticker, and H_2O to make 1 gal (decanted)	BSF	2.65	67-344	Y=2.35X+46.59	.9873
50% Dipel LC, 50% H_2O	Rhod B S	1.95	100-325	Y=1.93X+2.77	.9808
67% Dipel LC, 33% H_2O	Rhod B S	1.77	112-475	Y=2.35X-140.86	.9749
1/2 lb Dipel WP + 25% Sorbo and H_2O to make 1 gal	Rhod B S	1.69	64-592	Y=1.83X-19.32	.9950
1/2 lb Dipel WP + 25% Sorbo + 5% w/v Shade + H_2O to make 1 gal	Rhod B S	1.56	64-688	Y=2.00X-81.12	.9897
1 lb Dipel WP in 12.5% Biofilm, + H_2O to make 1 gal	BSF	2.79	86-344	Y=2.69X+23.21	.9762
1 lb Dipel, 0.125% Biofilm	Rhod B S	1.74	75-550	Y=2.04X-48.70	.9973[2/]
25% Thuricide HPC, 25% CIB, 3% sticker, and 47% H_2O	BSF BSF	2.24 2.06	92-516 92-516	Y=2.40X-31.45 Y=2.29X-42.78	.9560 .9590[3/]
50% Thuricide 16B, 50% H_2O	Rhod B S	1.88	87-525	Y=1.87X+1.30	.9976
25% Thuricide 16B, 75% H_2O	Rhod B S	1.94	100-300	Y=1.91X+5.45	.9951
50% Thuricide 16B, 0.2% w/v $FeCl_3$ and H_2O to make 1 gal	No dye	2.13	97-548	Y=2.04X+16.24	.9816
33% Thuricide 24B, 67% H_2O	Rhod B S	2.17	86-387	Y=2.32X-28.58	.9910
25% Thuricide 32B, 50% H_2O, 25% Sorbo	Rhod B S	1.64	86-333	Y=1.80X-24.69	.9944
50% Sandoz V[5/], 50% H_2O[4/]	No dye	1.62	129-280	Y=1.87X-46.85	.9652
25% CIB, 75% H_2O[4/]	BSF	1.99	43-430	Y=1.57X+61.85	.9848
25% CIB, 0.5 lb/gal Shade + H_2O to make 1 gal[4/]	BSF	1.94	70-323	Y=2.00X-10.15	.9769

[1/] Rhod B S is Rhodamine B extra S and BSF is Brilliant Sulpho Flavine FFA.

[2/] Printflex cards.

[3/] Kromekote cards with glossy coat on one side.

[4/] Carrier for nucleopolyhedrosis virus (NPV) formulation for Douglas-fir tussock moth.

[5/] An aerial adjunct for virus formulation from Sandoz Co.

Table 2 depicts a variety of oil- and water-base chemical insecticidal formulations; the variation of spread factor according to the formulation of a particular insecticide is of special interest. Several insecticidal carriers are also included in table 2.

Table 2--*Spread factor and linear relationship between spot (y) and drop (x) diameter for chemical insecticides on Kromekote cards*

Formulation	Dye[1/]	Mean spread factor	Range (spherical drop diameter μm)	Linear regression equation	Correlation coefficient
Oil base					
0.01 lb/gal Bioethanomethrin, 1% Wingstay 100[2/] in Klearol to make 1 gal	Rhod B	4.30	86-344	Y=4.57X-46.38	0.9789
0.01 lb/gal Bioethanomethrin, 1% Wingstay 100[2/] in Panasol to make 1 gal	Rhod B	5.70	86-237	Y=6.06X-51.34	.9519
0.1 lb/gal Pyrethrins, 5.6% Dowanol DB, 89.2% heavy mineral oil, 3.6% stabilizers	Oil red O Oil red O	6.06 5.64	129-430 129-430	Y=6.74X-139.82 Y=6.53X-183.20	.9994 .9956[3/]
67% Dylox 1.5, 33% Orchex 796	Rhod B	2.20	129-688	Y=2.13X+9.66	.9948
Dylox 1.5 oil undiluted	Rhod B	2.31	64-344	Y=1.91X+70.48	.9847
Dylox 4 undiluted	Rhod B	3.91	108-688	Y=4.15X-37.52	.9976
Fuel oil #2	Rhod B	4.82	43-258	Y=5.26X-42.77	.9923
Sevin-4-oil undiluted	Rhod B	2.18	70-194	Y=2.07X+17.24	.9742
25% Sevin-4-oil, 75% fuel oil #2	Rhod B	4.09	76-344	Y=4.30X-42.56	.9941
67% Sevin-4-oil, 33% fuel oil #2	No dye No dye No dye	2.13 2.12 2.38	129-297 129-297 129-297	Y=2.47X-63.60 Y=2.37X-47.67 Y=2.40X-4.05	.9519 .9526[4/] .9513[5/]
50% Sevin-4-oil, 50% fuel oil #2	Rhod B	2.31	86-443	Y=2.40X-20.59	.9945
10% Sumithion, 20% Panasol, 70% fuel oil #2	Rhod B	4.32	86-312	Y=5.60X-235.78	.9915
Dowanol TPM (carrier for Zectran)	Sudan Deep Black	4.93	43-301	Y=5.46X-60.74	.9905[3/]
Dowanol TPM (carrier for Zectran)	No dye	7.69	65-387	Y=9.45X-202.49	.9944[4/]
10% Zectran FS 1.5, 90% fuel oil #2	Rhod B Rhod B	4.87 4.86	65-473 65-473	Y=5.60X-107.71 Y=4.90X-70.58	.9901 .9893[3/]
10% Zectran FS 1.5, 90% Chevron C	Rhod B	3.99	75-430	Y=4.86X-123.12	.9957[3/]
Water base					
0.25 lb Dimilin 25% WP + H_2O to make 1 gal	Nigrosine	1.99	194-441	Y=1.89X+30.99	.9737
0.5 lb Dimilin 25% WP + H_2O to make 1 gal	Nigrosine	1.81	129-473	Y=1.70X+29.84	.9865
1 lb Dimilin 25% WP + H_2O to make 1 gal	Nigrosine	2.14	86-602	Y=2.32X-44.24	.9971
1 lb Dimilin 25% WP, 10% Ethylene glycol, in H_2O to make 1 gal	Rhod B S	2.18	86-430	Y=2.28X-16.46	.9971
Imidan IE undiluted	Rhod B	4.57	129-322	Y=4.77X-23.79	.9991
75% Imidan IE, 25% H_2O	Rhod B	3.97	97-473	Y=5.15X-204.72	.9995
50% Imidan IE, 50% H_2O	Rhod B	4.90	86-280	Y=4.37X+95.37	.9918
1 lb Orthene 75SP in H_2O to make 1 gal	Nigrosine	2.18	43-494	Y=2.41X-49.44	.9880
1 lb Orthene 75SP, 10% Ethylene glycol in H_2O to make 1 gal	Rhod B S	1.75	86-860	Y=1.89X-38.09	.9992
1 lb Orthene 75SP, 0.1% w/v $FeCl_3$ in H_2O to make 1 gal	No dye	2.06	86-387	Y=2.22X-33.39	.9788

1/ Rhod B is Rhodamine B extra base.
2/ Manufactured by B. F. Goodrich Co.
3/ Kromekote cards with glossy coat on one side.
4/ Red-dyed Kromekote.
5/ Blue-dyed Kromekote.

The first part of table 3 indicates that the type or concentration of dye may make a difference in the spread factor. When distilled water was used as a solvent, spread factor differences up to 17 percent were found for different dyes (0.5 percent Nigrosine vs. 0.5 percent Calcofluor) and up to 11 percent for different concentrations (0.1 percent Nigrosine vs. 0.5 percent Nigrosine). Adding a wetting agent to water greatly increased the spread factor (water + detergent + 0.1 percent Nigrosine vs. water + 0.1 percent Nigrosine). The spread factors of a few fertilizers and herbicides are shown at the bottom of the table.

Table 3--*Spread factor and linear relationship between spot (y) and drop (x) diameter for water, herbicides and fertilizers on Kromekote cards*

Formulation	Dye	Mean spread factor	Range (spherical drop diameter μm)	Linear regression equation	Correlation coefficient
Water					
Distilled water + detergent	0.1% Nigrosine	2.77	75-344	Y=2.89X-18.17	0.9779
Distilled water	.1% BSF	1.85	32-387	Y=1.76X+10.91	.9958
Distilled water	.1% Rhod B S	1.72	75-602	Y=1.81X-19.32	.9951
Distilled water	.1% Nigrosine	1.63	100-500	Y=1.90X-57.99	.9896
Distilled water	.5% Nigrosine	1.82	129-430	Y=1.64X+38.72	.9715
Distilled water	.5% Calcofluor	2.18	118-366	Y=1.85X+67.14	.9324
Herbicides and Fertilizers					
1723.0 g nitrogen, and H_2O to make 1 liter	Nigrosine	2.71	65-409	Y=2.93X-31.35	.9866
422.6 g nitrogen, and H_2O to make 1 liter	Nigrosine	2.76	129-705	Y=2.67X+27.17	.9900
16.3 g 2,4,5-T, and H_2O to make 1 liter	Nigrosine	2.86	27-2000	Y=3.08X-37.78	.9993
2 lb Benlate, and H_2O to make 1 gal	Rhod B S	2.42	108-731	Y=2.70X-92.45	.9949

Several complicating factors are evident in spread factor determination. Halo effects around spots can be caused by the unequal spreading of different ingredients in certain formulations. They can also be formed if the sampling card is damp. Precautions should be taken to prevent dampening of cards. The exact conditions of dampness for a spread factor calibration cannot be matched in the laboratory.

Another problem is that of irregular spreading of certain formulations. The drop forms an irregular or noncircular shaped spot. These are measured by taking an average of the maximum and minimum dimensions.

Two problems occur with the vibrating reed droplet generator due to the type of formulation used. First, water-base formulations differ from the oil-base formulations in that they do not generally form the two streams of uniform size droplets as the vibrating reed removes liquid from the syringe. Often it is very difficult to isolate streams of droplets of uniform size, and it becomes a matter of patience.

Second, some formulations contain particulates which settle and often plug the syringe needle. This problem can be minimized by providing constant agitation.

The tables show the linear regression equation for each formulation with the range of spherical droplet diameters which were measured to determine this equation. The experimental mean spread factor may be utilized as a close approximation

for calculations. The spread factor does not take into account, however, the variation of spread factor with droplet size. The correlation coefficient is greater than 0.95 in all cases except one, showing an excellent correlation between drop and spot size. Most of the work was done on white Kromekote paper--coated on both sides. A few other surfaces have been used such as Kromekote coated on one side, printflex, oil-sensitive red-dyed Kromekote (white Kromekote dipped in acetone with red dye), and blue-dyed Kromekote.

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METRIC CONVERSIONS

1 gallon = 3.785 liters
1 fluid ounce = 29.57 milliliters
1 pound = 453.59 grams
1 pound per gallon = 119.84 grams per liter

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife -- if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

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